J. Fish. Sci. Tech. 4(3), 150~158, 2001

JOURNAL OF
FISHERIES SCIENCE
AND TECHNOLOGY

Distribution Characteristics of Bottom Litter in Chinhae Bay, Korea

Jong-Hwa Kim*, Sam-Kon Kim[1] and Jong-Kyu Kim[2]

Department of Ship Training, Pukyong National University, Pusan 608-737, Korea
[1]Department of Fisheries Education, Pukyong National University, Pusan 608-737, Korea
[2]Department of Ocean Engineering, Pukyong National University, Pusan 608-737, Korea

(Received June 2001, Accepted September 2001)

A study on the amount, distribution and item of bottom litter on the sea-bed was conducted by the bottom trawl net at 5 sections in Chinhae Bay over a year. The number and weight of litter found per unit of swept area (1 hectare) in each section were estimated as the range of 8.76~80.63 pieces, 3.51~108.39 kg, respectively. The seasonal variation of high (Aug., '97) and low season (Feb., '98) in quantity was small, and it was about 2 times as the range of 24.58~52.61 pieces/ha between them. But the weight variation between high (Apr., '98) and low season (Aug., '97) was very large, about 30 times as the range of 4.06~119.64 kg/ha. The largest and second composition on the weight of bottom litter in Chinhae Bay are 76% in other-litter with compound and bulky materials, and 9.3% in fishing gear, respectively. The relationship between quantity and weight of bottom litter was not occurred due to the variety of specific gravity. Of the fishing gear, fishing nets was portioned to be 2.571 kg/ha in weight and 84.9% in composition. So these results prove that fishing nets were discarded as the most part of fishing gear during fishing activity in the bay. The largest composition of the soiled state classified into 3 styles in overall bottom litter was 69% in very soiled state, and the second one of 28% in the soiled state. On the other hand, new state is very small and portioned in 3.0% of all. Chinhae Bay was estimated to be about 10 times in quantity and about 36 times in weight of Tokyo Bay. Therefore, these suggest that Chinhae Bay is a very serious polluted estuary caused by the bottom litter such as heavy and bulky wastes, fishing gear.

Key words: Bottom litter, Swept area, Seasonal variation, Composition, Fishing gear, Soiled state, Bulky wastes, Polluted estuary

Introduction

In recent years, marine pollution caused by plastic litters (fishing nets, packing bands, plastic film, plastic bottles and styrofoam, etc.) floating into the coastal estuaries and the ocean has become a big problem and furthermore developed into a major global environmental issue. Plastic debris floating into the ocean causes many problems, particularly floating fishing nets and ropes by entangling marine creatures such as seals, sealions, turtles, fishes, etc. or with propellers of vessels causing navigational problems (Laist, 1987; Shaughnessy, 1980; Gramentz, 1988; Yosida and Baba, 1987).

Moreover, if this litter beached on the shore leads to impairment of environmental beauty (Younger and Hodge, 1991). Plastic litter in the ocean also affects the marine ecosystem by sinking to the sea-bed, accumulating, and causing the fishing grounds to be devastated and polluted.

The researches on plastic litter in the marine environment have mainly focused on floating plastics (Dixon and Dixon, 1983; Pruter, 1987; Kim et al., 1997; Kim, 1999). And there are few reports on plastic present on the sea-bottom layer (Kanehiro et al., 1995).

In this study, Chinhae Bay was selected to obtain background information on the bottom litter, which present in the estuarine environment. The bay is known well as the most polluted estuary in the

*Corresponding author: kimjh@pknu.ac.kr

Korea Peninsular since 1970's. For this reason, many researches were conducted in various subjects under the oceanographic conditions such as physical, chemical and geological features, hydro-meteorological phenomena, pollutant dispersion and their numerical modeling. But there is not a research reported on the bottom litter in the bay.

The aim of the study is to show several knowledges obtained from the composition and distribution of bottom litter in Chinhae Bay and reveal the seriousness of poilution of marine litter on the sea -bed.

Study area

The southern coast of the Korean Peninsular is characterized by many coastal embayments and islands, related to the postglacial transgression. Chinhae Bay, covering an area about 680 km^2 and mean depth about 12.5 m under the MSL (mean sea level), includes several small bays such as Masan Bay (Sect. 5), Chinhae harbor with Hangam Bay at the northern coast of Sect. 3, Jindong Bay near Sect. 7, Gohyun Bay (Sect. 9) in the northwest part of the Geoje Island (Fig. 1). This day is important area as a commercial harbor (Sect. 5) and a naval base in Chinhae harbor near Sect. 3. The bay also is one of the most productive areas for filter feeding mollusks such as oyster, ark shell, and mussel which grow by uptake of suspended particles in the sea waters at the western part of Chinhae Bay near Sects. 7 and 9 (Choi et al., 1998). And also there is a large shipyard at the southern coast of Gohyun Bay (Sect. 9).

The bay is shallow (10~40 m) and connected to the offshore mainly through the Gadeog Channel in the eastern part of the bay. The topographic configuration has influence on the tidal flow, and it is exchanged through southern channel of Gadeog island (Kim, 1984).

And also, the bottom waters of the inner part of the bay are not well mixed with those of the outer bay, because of the distinct nature of the semi-enclosed basin. The flow scales of the inner bay is shown as the very weak current velocities of <0.1 kn (Korea Hydrographic Office, 1982) and somewhat isolated from the main axis of tidal current in the eastern sea of the Geoje island near Sect. 1 (Kim et al., 1989; Hong, 1998). The tide of the bay is semidiurnal, with a tidal range between 2.1 m during the spring tide and 0.3 m during the neap tide (Korea Hydrographic Office, 1986). The drainage system is extremely limited except a few streams in the northern part (Sect. 5) of the bay. And Masan Bay, Sect. 5, gets used to offer mainly the various solute material sources of Chinhae Bay (Nam, 1982; Kang et al., 1989; Kim et al., 1986; Lee et al., 1993).

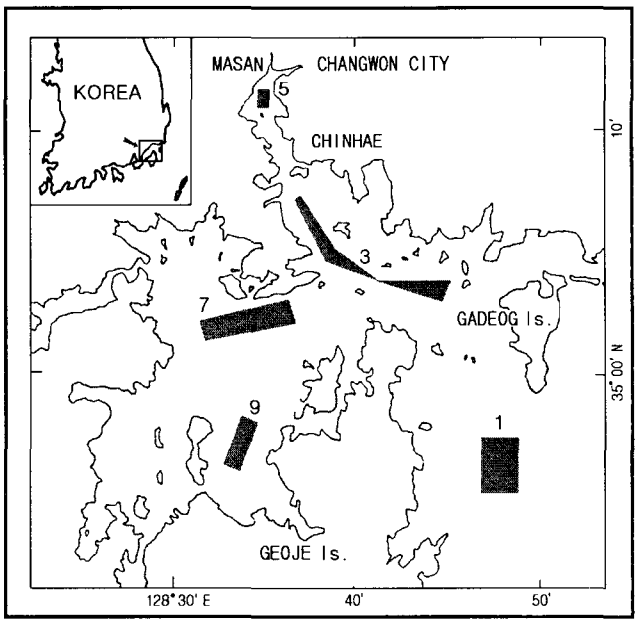

Fig. 1. Location map sampled for bottom litter in Chinhae Bay.

Material and Methods

Litter surveys were conducted by the bottom trawl net, and also the quantities, type of litter and their distribution were investigated. The field survey was conducted six times bimonthly during a year from 1997 to 1998. The survey sections sampled on each cruise are shown in Fig. 1 and the survey areas are divided into 5 sections (Sects. 1, 3, 5, 7 and 9) being representative over the bay. A beam trawl vessel (G/T: 7.93 ton) was used to collect the litter in the survey. Each trawl was pulled for 5~35 min duration and covered a 5.9 m wide path in breadth of beam. The ship's speed and position were determined by GPS (Global Positioning System) receiver. The crusing conditions for each survey are shown in Table 1. It is a worthy note that each section was

Table 1. Survey details of trawling on the sea-bed of Chinhae Bay (1997~1998)

Date	Section number	Depth (m)	Towing speed (kn)	Duration towed (min)	Catches of fishes	Bottom litters	Remarks
Aug. 21~22 1997	1	32	1.3	30	yes	yes	
	3	10	2.3	5	yes	no	Crowded many pots
	5	8	1.9	15	no	yes	Rotten mud, jelly fish
	7	20	1.6	30	yes	yes	Rotten mud
	9	21	2.0	5	no	yes	Many aquaculture field
Oct. 28~29 1997	1	25	1.8	20	yes	no	Much mud
	3	12	2.0	18	yes	yes	
	5	12	1.8	20	yes	yes	Rotten mud, jelly fish
	7	19	1.8	30	yes	yes	
	9	18	2.0	30	yes	yes	
Dec. 19~20 1997	1	–	–	–	–	–	High wave, no trawling
	3	12	2.0	30	yes	yes	
	5	11	1.6	25	yes	yes	Rotten mud, jelly fish
	7	19	2.2	30	yes	yes	
	9	24	2.2	30	yes	yes	
Feb. 28~ Mar. 1 1998	1	31	2.0	32	yes	yes	
	3	18	1.8	33	yes	yes	
	5	8	1.6	24	yes	yes	Rotten mud, jelly fish
	7	20	2.2	35	yes	yes	
	9	22	2.2	26	yes	yes	
Apr. 30~ May 1 1998	1	30	1.9	22	yes	yes	Red tide
	3	18	1.9	20	yes	yes	Red tide
	5	7	1.4	33	yes	yes	Rotten mud, jelly fish
	7	21	2.2	21	yes	yes	
	9	24	2.1	20	yes	yes	
Jun. 28~29 1998	1	30	2.2	20	yes	yes	
	3	14	2.2	17	yes	yes	Many jelly fish
	5	9	2.0	18	yes	yes	Many jelly fish, rotten mud
	7	20	2.4	20	yes	yes	
	9	24	1.9	25	yes	yes	

described the sea conditions during the survey duration in the remarks column of Table 1. Bottom litters collected from the trawl net were classified into 6 categories: (1) fishing gears, (2) textiles, (3) plastics, (4) metal & glasses, (5) wood & papers and (6) others (heavy and group items like shells, tires, etc.).

The collected litter was washed with fresh water before classifying, weighing of amounted the each item and the quantity and composition were analysed. The items and total weight of litter found on the sea-bed in the bay are shown in Table 2. The numbers of identified items were 46 types. Among the first three categories of litters, almost all were the synthetic polymers composed of various types of resin.

In order to deduce the state piled up on the sea-bed and the finding of litter sources, soiled state of litter were classified into 3 types: (a) very soiled (old ones which seemed to be longly elapsed since disposed of), (b) soiled and (c) new (new ones without soil which seemed to be shortly elapsed since disposed of).

In the survey, compound bulky wastes were collected and classified into sub-items. And also fish catches identified were measured of numbers, weight and length over all fish species.

Results

Quantity and weight of litter

Quantity and weight of bottom litter collected in Chinhae Bay are shown in Tables 3 and 4. Table 3 represents the sectional variability of quantity and weight. Twenty seven hauls were carried out at 5 sections, total swept area is 22.97 ha, the total num-

Table 2. Items and weight of litter found on the sea-bed of Chinhae Bay (1997~1998)

Categories	Weight (kg/ha)	Types	Items of litter
Fishing gear	3.028	3	Fishing ropes & lines Fishing nets Fishing pots (octopus, sea eel)
Textile	0.837	11	Clothing Gloves Hat Vinyl bags Bits of vinyl Burlap bags Confectionery packages Shoe brush Balls Towel Socks
Plastic	0.857	10	Bottles (beverage, food, detergent) Bags (shopping) Slippers Egg supports Food trays and containers Sheeting Electric wire Household electric appliances (radio, tape recorder, etc.) Toys Rubber goods
Metal & Glass	2.253	10	Metal bottles Metal cans Paint cans Aluminum ware Metal wires Metal drums Metal battery Pieces of metal Glass bottles (beverage, food, liquor) Pieces of glass
Wood & Paper	0.655	7	Bamboo Wood lumbers Wood pieces of lumber Paper dumps Paper cartons Milk packs Lump of charcoal
Others	24.820	5	Shells Pinecone Tires Motorcycle Refrigerator

ber and weight collected are 861 pieces and 745.386 kg, respectively.

The number and weight of litter found per unit of swept area (1 hectare) in each station were estimated as the range of 8.76~80.63 pieces, 3.51~108.39 kg, respectively. The highest densities of numbers, Masan Bay (Sect. 5) has 9 times as those as in lowest section, the entrance of Chinhae Bay (Sect. 1). The variation of the densities of weight is very large about 30 times between low (Sect. 1 or 7) and high section (Sect. 9) near north part of Geoje Island.

Table 3. Sectional variability of bottom litter on the quantity and weight in Chinhae Bay

Section Number	1	3	5	7	9	Total areas
No. of trawling	4	5	6	6	6	27
Swept area (ha)	3.54	4.21	4.13	6.31	4.78	22.97
Collected number (Total p'cs)	31	204	333	81	212	861
(No./ha)	8.76	48.46	80.63	12.84	43.93	37.4
Collected weight (Total kg)	13.365	97.608	93.138	22.15	518.125	745.386
(kg/ha)	3.78	23.18	22.79	3.51	108.39	32.4

Table 4. Seasonal variability of bottom litter on the quantity and weight in Chinhae Bay, 1997~1998

Month	August	October	December	February	April	June
No. of trawling	4	4	4	5	5	5
Swept area (ha)	2.395	3.39	4.19	5.33	3.81	3.85
Collected Number (No./ha)	52.61	27.14	50.12	24.58	28.61	49.61
Collected Weight (kg/ha)	4.06	5.19	11.32	7.75	119.64	45.05

The seasonal quantity and weight of bottom litter are shown in Table 4. As shown in here, the seasonal variation of high (Aug., '97) and low season (Feb., '98) in quantity was small, and it was about 2 times as the range of 24.58~52.61 pieces/ha. But the weight one between high (Apr., '98) and low season (Aug., '97) was very large, about 30 times as the range of 4.06~119.64 kg/ha.

Figure 2 represents the weight composition of bottom litter in Chinhae Bay. Upper part of circular shape means sectional composition, middle part seasonal one and lower part item's. In upper part, section 9 composed of the largest bottom litter was occupied 68% of the whole weight. The lowest percentage was 2% in Sect. 1 and 7. In middle part, the largest portion of seasonal composition was of

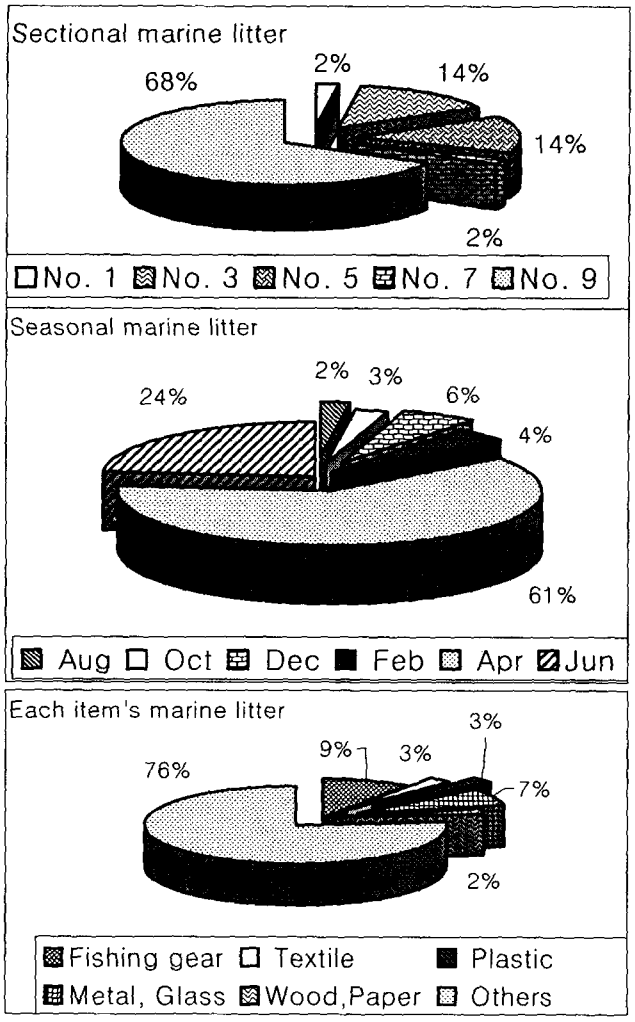

Fig. 2. Weight composition of bottom litter in Chinhae Bay.

61% in April and the second, 24%, in June. In lower part of items, the largest and second composition are the other-litter (76%) with compound and bulky materials and the fishing gear (9.3%), respectively.

The relationship between quantity and weight of bottom litter is shown in Fig. 3. But their correlation is not recognized apparently as represented in Fig. 3. It means that the specific gravity what averaged of litter in each season and section on the weight and quantity has many varieties. For example, the weight per unit piece is ranged from 0.03, in August of Sect. 5, to 17.51 in April of Sect. 9.

Others (compound and bulky litter) and fishing gear

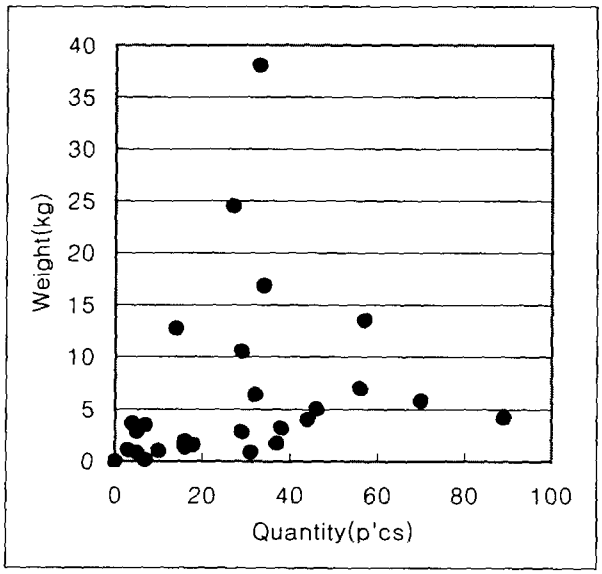

Fig. 3. Correlation between quantity and weight of bottom litter.

The compound and bulky wastes categorized as other-litter are shown in Table 5. Others composed of 76% through the overall litter's weight was subdivided into 5 items. The percentage of tires was occupied 89.4% as the most part of other-litter. On the sectional distribution there was composed of 73.7% in Sect. 9.

Therefore, the highest section piled up with the other-litters was Sect. 9 and also the weight of them was 90.85 kg/ha.

The fishing gear was shown as the most weight except other-litter as the lower part of Fig. 2. The role of fishing gear implies importance in this bay. Figure 4 shows the sectional and seasonal change of fishing gear, upper part represents sectional variability in weight per ha and lower one is seasonal. A remarkable feature in sectional distribution was

Table 5. Other-litter collected on the sea-bed in Chinhae Bay (unit: kg/ha)

Sub-item	Section number					Mean	Percentage (%)
	1	3	5	7	9		
Shell	2.26		0.07	1.27	2.11	1.15	4.6
Pinecone					4.64	0.97	3.9
Tires		10.83	17.92		81.59	22.18	89.4
Motorcycle					1.99	0.41	1.7
Refrigerator					0.52	0.11	0.4
Sum	2.26	10.83	17.99	1.27	90.85	24.82	100
Percentage (%)	1.8	8.8	14.6	1.1	73.7		100

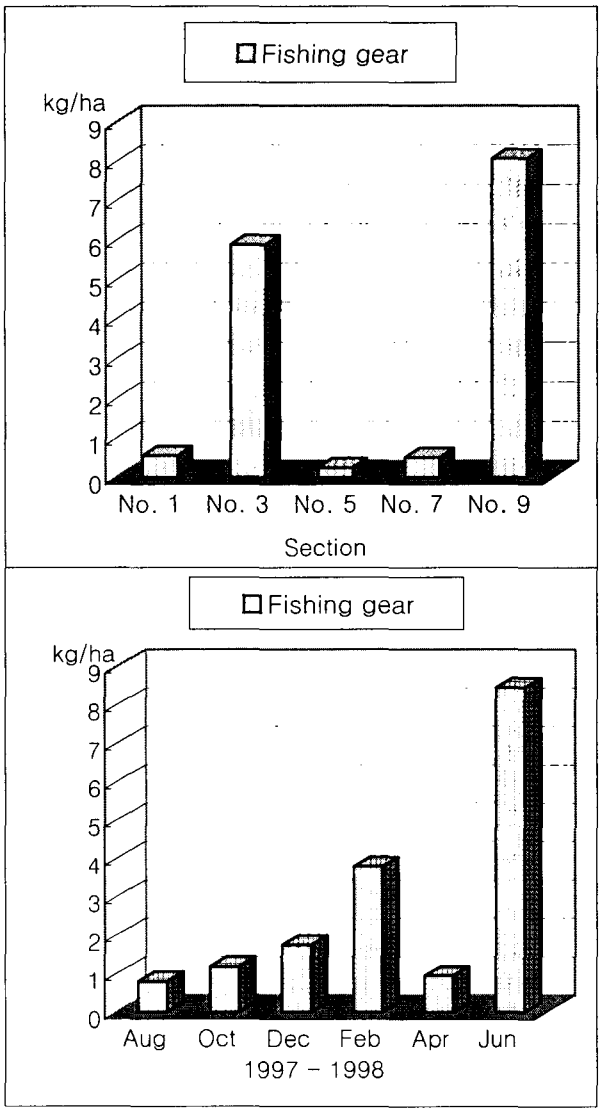

Fig. 4. Sectional and seasonal change of fishing gear in Chinhae Bay.

discovered that Sect. 9 near northwestern part of Geoje Island and Sect. 3 in central part of Chinhae Bay were collected much more litter than the other section of the bay. It means that these areas are the fishing ground where the fishing activity by vessels or aquatic fishing as shown in remark column of Table 1. In this survey, in fact, several cases observed of dead fishes were entangled or caught by netting fragments or in sea eel pots.

In the seasonal change of fishing gear, we can be apparently recognized the highest density at June, 1998, and seasonal trend of change is radically growing up from August to June except April, 1998. At Spring season, Chinhae Bay is active in fishing. Lower amount in August is seemed to be the effect of the precipitation in July.

The fishing gear was subdivided into 3 items with fishing ropes & lines, fishing nets and fishing pots (Octopus, Sea eel, etc.). Their quantities and weight are shown in Table 6. Among them, fishing nets was portioned to be 2.571 kg/ha in weight and 84.9 % in composition. This percentage proves that fishing nets are discarded as the most part of fishing gear during fishing activity in the bay.

Table 6. Categories, quantities and weight of fishing gear in bottom litter

Sub-item	Quantity (piece)	Weight		Composition of weight (%)
		Total (kg)	kg/ha	
Fishing rope & lines	12	3.63	0.158	5.2
Fishing nets	23	59.065	2.571	84.9
Fishing pots (octopus, sea eel)	13	6.85	0.298	9.9
Sum	48	69.545	3.028	100

Soiled state in litter

The soiled state related directly to the marine creatures takes an important role in index of polluted extent. The soiled state classified in categories of litter is shown as Fig. 5 with 4 shapes of circular. The largest composition of the state in overall bottom litter was 69% in very soiled state, the next was 28% in the soiled state. On the other hand, new state is very small and portioned in 3.0% of all. Fishing gear, textile & plastic, and metal & glass litter in Fig. 5 were very similar to those of overall bottom litter. These mean that bottom litter in the bay was nearly all very old to be discarded and represent the natural features of semi-enclosed bay.

Discussion

Distribution and composition of bottom litter

Masan Bay (Sect. 5) positioned at the northern part of Chinhae Bay is enclosed by Masan and Changwon city, and over a million civilians inhabit in the cities. For reason of that, the quantity per unit was highest but weight was lowest, many pieces of life litter are piled up to inflow from land and also soiled, mixed up with mud on the sea-bed.

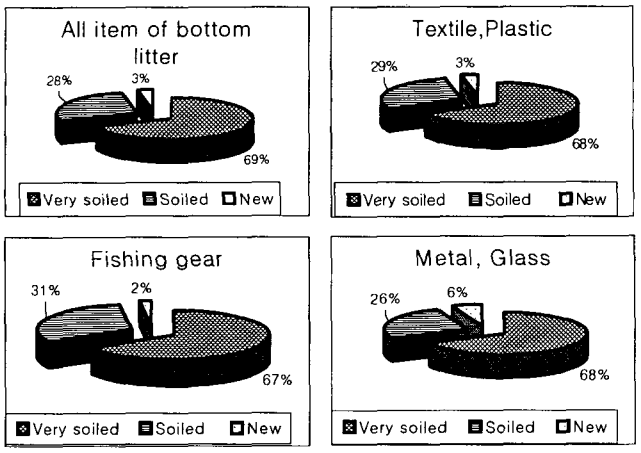

Fig. 5. Soiled state of all and each item in bottom litter.

These phenomena caused by the weak current in bottom layer flow were always discovered in hauling up the bottom litter in the field surveys, as shown in Table 1 (Kim et al., 1986; Kang et al., 1989).

The seasonal features were revealed that the quantity of bottom litter in August is largest but weight is lowest. In view of rainy season for the duration from the middle of June to August over the year in Chinhae Bay, Korea (Korea Meteorological Administration, 1999; Fig. 6), there is considerable validity in this results. With the survey in August, the household products of textile & plastic such as vinyl bag, confectionery package, detergent bottle and food tray & container were dominated.

We see from the sectional weight composition (Fig. 2) and sub item (Table 5) that the bulky litter in Gohyun Bay (Sect. 9), especially such as tires and shells, has much scattered. It seemed to be caused by the many aquaculture farm's activity (Choi et al., 1998).

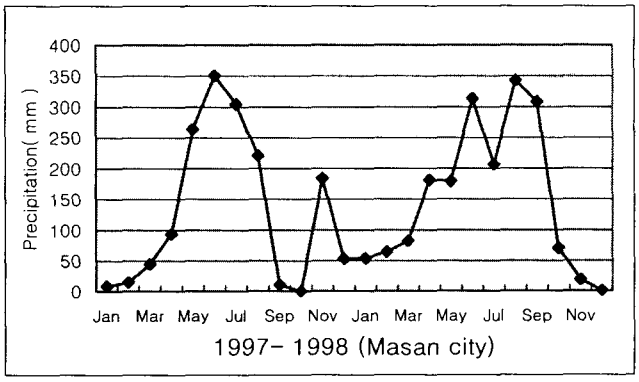

Fig. 6. Curve of precipitation during field surveys in Chinhae Bay.

Comparison of litter in Chinhae and Tokyo Bay

The quantity and weight of bottom litter in Chinhae and Tokyo Bay (Kanehiro et al., 1995) was shown in Table 7. Other-litter was excluded here for concerning with each item of Tokyo Bay. Chinhae Bay was estimated to be 10.5 times in quantity and 36.3 times in weight of Tokyo Bay. These mean that Chinhae Bay is a very serious polluted estuary.

Their composition on each item is shown in Fig. 7. Of items, fishing gear's rate of Chinhae Bay was 39.8% but Tokyo Bay was 14%. On the other hand, wood and paper were 32.9% in Tokyo Bay, but 8.5 % in Chinhae Bay.

Table 7. Comparison of bottom litter in quantity and weight between Chinhae and Tokyo Bay

Estuary	Quantity (No./ha)	Weight (kg/ha)	Collected year
Chinhae Bay	32.7	7.58	1997~1998
Tokyo Bay	3.1	0.21	1989~1994
Rate (C/T)	10.5	36.10	

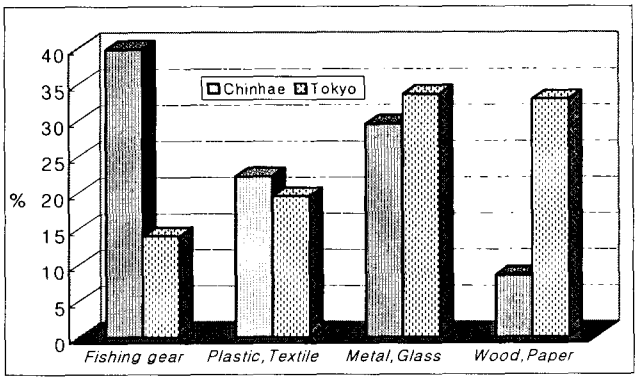

Fig. 7. Weight composition of bottom litter between Chinhae and Tokyo Bay.

Therefore, Chinhae Bay is crowded with artificial litters made by plastic fabrication materials. In view of quantitative and qualitative points, Chinhae Bay was very seriously polluted.

The fishing gear collected in total were 48 pieces (Table 6), and those of Tokyo Bay were 116 pieces for 4 years. It is difficult to compare the quantity due to the difference of swept area and collected year. The results of quantity composition of fishing gear in Chinhae and Tokyo Bay were shown in Fig. 8. Comparing their percentage of sub items for Tokyo Bay, their distribution is even to as 30.2%,

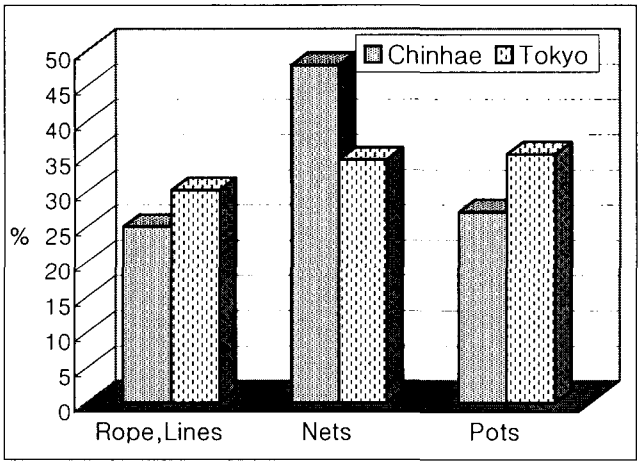

Fig. 8. Quantity composition of fishing gear between Chinhae and Tokyo Bay.

fishing rope & lines, 34.5%, fishing nets and 35.3%, fishing pots, respectively (Kanehiro et al., 1995). As shown in Fig. 6, the comparative figures in both bay is different in fishing activities, namely, Chinhae Bay is active in fishing with nets, but with pots and ropes, Tokyo Bay.

The percentage of fishing gear may seem to be small in relation to the other types of litter (plastic or metal, glass), but the sub items in this category are more of a hazard to marine creatures compared to other litter items, for example, ghost fishing phenomena, environmental hormone materials.

The soiled state of Tokyo Bay was revealed that very soiled state is of 56.6%, soiled one 34%, and new one 9.4% (Kanehiro et al., 1996). Though the percentage of the state in Chinhae Bay is more or less different from Tokyo Bay. The trend of it is similar to those of Tokyo Bay.

Conclusions

This study deals with the bottom litter which has sunk and accumulated on the sea-bed of Chinhae Bay, Korea. The overall distributions of bottom litter in the bay are largely widespread in quantity and weight. Masan Bay, Sect. 5, positioned at the northern part of Chinhae Bay, was the sector with the highest density in quantity but with the lowest in weight. These results are caused by a great population and the weak current on the sea-bed of the bay. On the other hand, Gohyun Bay, Sect. 9, was the sector with the highest density in weight. In this sector, the heavy and bulky wastes called other litter were hauled up 76% of overall litter, because of concentrating the aquaculture such as oyster culture farms and a huge shipyard near the coast of northwestern part of Geoje island. Considering the seasonal variability of bottom litter, the quantity of litter is largest in August but weight is lowest than other season. Actually, household products of light litter were collected as the most common in August. Among the general litter generated by ocean-based sources such as fishing activity and land-based ones such as industrial activity, household life except other (bulky and heavy litter), fishing gear was occupied the most portion in the bay. A remarkable feature in fishing gear distribution is shown that Sect. 9, and Sect. 3 in central part of the bay were much more collected than the other section and, especially, fishing net among 3 items of fishing gear. The composition of the state in overall bottom litter is 97% in the very soiled and soiled state. And, new one is only 3%. It was revealed that all over Chinhae Bay had been very polluted with bottom litter. In this study, especially, Masan Bay used to be hauled many jelly fishes over the duration of a year and were not seen a school of any fishes. Chinhae Bay was estimated to be about 10 times in quantity and about 36 times in weight of Tokyo Bay. It was proved that Chinhae Bay is a very serious polluted estuary than Tokyo Bay.

Therefore, it is concluded that the Chinhae Bay, this study area, was already serious polluted with bottom litter such as heavy and bulky litter, fishing gear, and plastic materials and generated mainly by three factors: the first is collective aquacultural farms at the western part of the bay, the second is a great population at northern part, and the third is some features of the bay such as semi-enclosed bay and weak current in the bottom layer.

To overcome marine pollution problems caused by bottom litter, it is important to promote social, economical and political problems to avoid disposal of litter in the marine environment. Thus, it is difficult to solve merely this problem by the efforts of persons engaged in fishing activity. On the basis of this data, the source position, quantity and inflow items of bottom litter are difficult to identify. It is hoped that further more surveys are continuously

being investigated and a much wider coverage can be achieved, then contributed to the stationary area, finding of land sources, removal method of bottom litter and resistance of marine productivity.

Acknowledgements

This paper is a result of research funded by the Ministry of Education (award No. KIOS-97-F-13). We would like to thank J.J. No, B.N. Choi, J.Y. Woo, J.S. Ko, C.S. Moon and captain of trawling vessel for sampling and analytical supports.

References

Choi, H.G., W.C. Lee, P.J. Kim and P.Y. Lee. 1998. Water and sediment characteristic in the shellfish farms of the western part of Jinhae Bay. *J. Fisheries Science and Technology*, 1, 159~167.

Dixon, T.J. and T.R. Dixon. 1983. Marine litter distribution and composition in the North Sea. *Marine Pollution Bulletin*, 14, 145~148.

Gramentz, D. 1988. Involvement of loggerhead turtle with the plastic, metal, and hydrocarbon pollution in the central mediterranean. *Marine Pollution Bulletin*, 19, 11~13.

Hong, C.H. 1998. On the circulation in the Chinhae Bay using the Princeton ocean model: 1. Characteristic in vertical tidal motion. *J. Fisheries Science and Technology*, 1, 168~179.

Kanehiro, H., T. Tokai and K. Matuda. 1995. Marine litter composition and distribution on the ses-bed of Tokyo Bay. *Fisheries Engineering*, 31, 195~199.

Kanehiro, H., T. Tokai and K. Matuda. 1996. The distribution of litter in fishing ground of Tokyo Bay. *Fisheries Engineering*, 32, 211~217 (in Japanese).

Kang, S.W., T.S. Chung, J.C. Lee and C.S. Kim. 1989. Circulation and dispersion of pollutant in Masan-Chinhae Bay. *Institute of Environmental Research, Kyungnam University*, 11, 47~72.

Kim, C.S., J.C. Lee, T.S. Jung and S.W. Kang. 1989. Application of a three-dimensional hydrodynamic model. *Ocean Research*, 11, 45~55.

Kim, J.H. 1984. Sea water exchange in Chinhae Bay. *MS thesis, Pukyong National University*, 36p (in Korean).

Kim, J.H. 1999. A study on the distribution and composition of floating debris in the coast of Korea: 2. Transport of debris in middle part of Southern Sea. *J. Korean Fisheries Society*, 32, 338~344 (in Korean).

Kim, J.H., S.D. Chang and H.R. Kim. 1986. A tidal exchange in Masan Bay. *J. Korea Fisheries Technology Society*, 22, 29~35 (in Korean).

Kim, J.H., S.K. Kim and C.D. Park. 1997. Distribution and composition of floating debris in the east coast of Korea. *J. Fisheries and Maritime Science Education*, 9, 31~39 (in Korean).

Korea Hydrographic Office. 1982. Tidal current chart (Pusan to Yosu). *Ministry of Traffic Department in Republic of Korea*, 23~24 (in Korean).

Korea Hydrographic Office. 1986. Marine chart (No. 206). Jinhae Man and Approaches.

Korea Meteorological Administration. 1999. The Monthly-Daily Reports of Temperature-Precipitation by Inter Net.

Laist, D.W. 1987. Overview of the biological effects of lost and discarded plastic in the marine environment. *Marine Pollution Bulletin*, 18, 319~326.

Lee, M.O., R.A. Falconer and J.H. Kim. 1993. The effect of wind stresses on the pollutant dispersion in a semi-enclosed bay. *The 25th Congress of International Association Hydrodynamic Research*, Tokyo, Augst 30-September 3, TS-D-3-3, 5, 85~92.

Nam, K.S. 1982. The flushing time in Masan Bay. *The Bulletin of Korea Oceanographic Research Development Institute*, 4, 1~10 (in Korean).

Pruter, A.T. 1987. Sources, qualities and distribution of persisternt plastics in the marine environment. *Marine Pollution Bulletin*, 18, 305~310.

Shaughnessy, P.D. 1980. Entanglement of Cape fur seals with man-made objects. *Marine Pollution Bulletin*, 11, 332~336.

Yosida, K. and N. Baba. 1987. Marine debris program in Japan. *The North Pacific Rim Fishermen's Conference of Marine Debris, Honolulu, Hawaii*, 12~16.

Younger, K.L. and K. Hodge. 1991. International coastal cleanup overview. *In Center for Marine Conservation Report, R. Bierce and K. O'hara, eds., Washington*, 1~87.